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springs in half of the screws, the effect of wear on the mean of the micrometer readings is practically eliminated.

(4) That the effects of wear have a slight tendency to diminish the original periodic errors of the screws.

On a probable Instance of periodically recurrent Disturbance on the Surface of Jupiter. By W. F. Denning.

I wish to call the attention of observers of *Jupiter* to the desirability of carefully examining the northern hemisphere of the planet in the mornings of 1901 February to ascertain whether there occurs or has recently occurred any striking outbreak of spots on the north temperate belt in about latitude +25°. At intervals of little more than ten years phenomena of this kind apparently affect this region, and in the suddenness of their formation and development, as well as in their rapidity of motion, they furnish greater extremes than have been witnessed in any other latitude of the planet.

When in the autumn of 1880 I observed the north temperate belt with a string of dark spots upon it (*Monthly Notices*, 1880 November, p. 46) I remembered that the same features had been presented in 1870 and 1871. In 1891 I reobserved them, and found the velocity of the spots slower than in 1880 (*Observatory*, 1891 October, p. 330). But it may be as well to allude briefly to the several phenomena which have led me to take up the view of their periodicity.

1850 March 27.—Mr. W. Lassell observed *Jupiter* with a power of 430 on his 24-inch reflector and made a drawing of the planet (*Monthly Notices*, 1850 April), which included two marked projections from the S. edge of the N. temperate belt.

1860 February 29.—Mr. J. W. Long, F.R.A.S., observing *Jupiter* with a 5-inch refractor, power 305, noticed a curious streak or oblique belt lying between the N. temperate belt and the N. equatorial belt. The object was examined by Mr. J. Baxendell, of Southport, on March 2, 5, 7, and several subsequent occasions; and he found that it "increased greatly in size and darkness," and became much extended in longitude, though the latitude of the extremities remained the same. When first seen on February 29 the streak ranged over about 7° in longitude, but by April 9 it had reached more than half round the disc. On May 3 it had spread itself over the complete circumference of the planet, and on May 6 the two ends considerably overlapped. Mr. Baxendell estimated on several datés the times of transit of the p. and f. ends across the planet's central meridian, and I have obtained some additional ones of both the ends and the centre from their positions on a series of drawings published in *Monthly Notices*, 1860 April, and in the *Proceedings* of the Lit. and Phil.

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Society of Manchester for the same month. From these data I obtain the following rates of rotation of the slanting belt :—

	Period h	 m	 s	
South preceding end	9	52	13	163 Rotations
Middle of the belt...	9	54	7	163 ,,
North following end	9	56	1	162 ,,

These values show a difference of $3^m\ 48^s$ in the relative times of the p. and f. ends. This is equivalent to $9^m\ 13^s$ in a terrestrial day, and proves that in sixty-four days (February 29 to May 3) the belt would distend itself completely round the planet, as was actually observed.

I believe that the outburst or eruption of dark material originated in the N. temperate belt,* and that its initial violence was such that it was forced in a direction southwards, the rapid rotatory movement of the planet being quite incapable at first of distending it in longitude. But immediately afterwards the effects of rotation became obvious, and the short belt, lying at first nearly N. and S., lengthened out, became less oblique, and finally, after an interval of sixty-four days, was transformed into one of the normal bands of the planet. Mr. Baxendell states that on April 20 the belt was of a remarkable bluish-black colour, and that condensations marked the ends and middle of it. The rate of velocity of the S. p. end appears to have increased rapidly with the time.

1870 August 12.—Very little alteration occurred in the dusky N. temperature belt during the opposition of 1869, but at the reappearance of *Jupiter* (1890 July) marked changes took place, according to Mr. Gledhill. On August 12 he noted that the belt appeared very rugged. On September 24 he observed and drew five well defined dark spots upon it (*Astronomical Register*, 1871). On November 25 Mr. J. Birmingham says it exhibited two dusky patches not previously seen. At a later period Mr. Gledhill noted some dark condensations both from its N. and S.

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* I am led to this view by the fact that the motion of the streak where it joined the N. edge of the N. equa. belt was characteristic of the great velocity of the current forming the N. temp. belt. It is true that the f. end of the slanting belt where it combined with the N. temp. belt moved very slowly; but this appears to me to afford strong proof that it was the material ejected which exhibited the greatest velocity of rotation, and not the actual seat of disturbance. If we regard the place of the latter as really represented by the N.f. end of the streak, and the disturbance as occasioned by a durable uprush from *Jupiter's* surface, then the true rotation period of the globe of the planet would be as nearly as possible $9^h\ 56^m$, as found by Cassini from Hooke's great southern spot of 1664, 1665, and following years. This conclusion is strengthened by the fact that the motion of the N.f. end of the streak was equable during the whole period, whereas the S.p. end and middle exhibited an increasing velocity. The variable rate of speed in the western part of the streak sufficiently showed that it could not have been actually joined to the solid globe of the planet, but probably consisted of material floating rapidly along in a region far above the surface.

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sides. In an article on "Telescopic Work" which I contributed to the *English Mechanic* of 1871 January 13 I included two drawings made by Mr. H. M. Whitley, of Truro, with a 6½-inch reflector in the autumn of 1870, and these show several well pronounced spots on the same belt. A drawing by Mr. James Cook, of Preston, with a 10-inch reflector on 1871 January 8, displays five spots in this latitude, which must evidently have been in a condition of great disturbance at this particular epoch.

1880 October 17.—Two black spots separated by 20° of longitude were detected by Mr. F. C. Dennett, of Southampton, on the N. temperate belt, which he describes as of a blue colour. These objects were seen by me at Bristol on October 24, and were closely watched during ensuing months. New spots were formed, and on December 30 I found they were spread over 270° of longitude. At the middle of 1881 January, after a visibility of ninety days, they quite encircled the planet and soon lost their distinctive character to form a new belt immediately south of the one on which they originally appeared. The rotation period of two of the principal spots was $9^h\ 48^m$. The disturbance was a striking one, and attracted widespread attention during its progress.

1890 October–November.—A considerable number of small black spots appeared at the close of the opposition of 1890 on the narrow belt about 9″ N., according to Mr. E. E. Barnard. When in the following year the planet favourably reappeared the spots had enlarged and were quite noticeable. One was seen by Mr. A. S. Williams on 1891 May 14, another by Mr. Barnard on July 11. In August I detected them, and on the 21st saw one which was quite as dark and prominent as a satellite-shadow when projected on the disc of *Jupiter* (*Observatory*, 1891 September, p. 312). I found the rotation period of one of the spots $9^h\ 49^m\ 27^s$; but the velocity slackened at the middle of September, and became $9^h\ 49^m\ 44^s$, according to Mr. A. S. Williams. The markings were seen by many observers, and some good photographs of them were obtained at the Lick Observatory.

I believe from the foregoing summary, incomplete as it is, that a fair case has been made out for further investigation. During the present year (1898) the N. temperate belt has been lying quiescent and extremely feeble in tone, for its aspect has been simply that of a delicate pencil shading, somewhat narrow, but in the usual position. This faintness may be only the prelude to the reintensification which we are fairly entitled to expect during the ensuing two years. But at the particular time antedating the periodical outbreaks to which I have been alluding the belt has not been consistently weak. In 1869 it was notably dark, and had actually become fainter in 1870, when numerously beaded with spots.

If the latter are periodically recurrent, as I assume from past observations, the intervals may not be always identical, for it is very possible there may be minor outbreaks or disturbances in the

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decade intervening between two maxima. In 1870–71, and again in 1890–91, the evidences of unusual activity in the belt remained visible for a long time, probably a year or more; but the recorded observations neither enable us to determine the length of the whole period or the precise dates of its earliest cyclical presentations. The evidence roughly indicates a period of 10·2 years, but it remains for future observation to finally affirm the fact of its occurrence and to accurately define the interval. Even if additional data fail to corroborate the views here formulated we shall at least have advanced a step nearer the truth, and shall be the more ready to relinquish our vague ideas as to distinctly periodical changes on *Jupiter*. For my own part I shall be willing to admit that many of his atmospheric features, though undoubtedly far more durable than our own, yet display many similar vagaries. I do not, however, anticipate that future experience will furnish a negative, but that when the planet is examined, either at a late period in the opposition of 1900 or at the earliest time in that of 1901, the north temperate belt will exhibit a similar disturbance to that which has marked it in the closing year of each of the last five decades. It is perhaps unfortunate that *Jupiter* will be in conjunction with the Sun in 1900 December, and that quite possibly the expected phenomena may in a great measure escape record. If *Jupiter* had been in conjunction in 1860 March and 1880 November the remarkable transformations of the belt which occurred at those epochs would never have become matters of history. It is to be expected, however, that, in the event of a well defined recurrence, the evidences of it will be favourably visible in the spring and summer of 1901. The duration seems to be very variable, for its chief intensity lasted about two months in 1860, three months in 1880, and certainly more than twelve months at its last apparition in 1890–91.

Bristol:
1898 *November* 30.

The Extra-equatorial Currents of Jupiter during the Apparition of 1897–98. By Rev. T. E. R. Phillips.

(*Communicated by W. F. Denning.*)

The following is a short discussion of the chief spots and currents visible on *Jupiter* during the last apparition outside the equatorial regions, omitting the three dark spots on the N. tropical zone which have been already discussed by Mr. Denning in the *Observatory* (May and September numbers).

Including the red spot, six distinct currents are denoted below, and it is noteworthy that only in the cases of the north north temperate belt, and, perhaps, a belt still further north